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Benzoylated hexa-2,4-dien-4-olides from aldono-1,4-lactones: stereoselective synthesis of dideoxyaldonolactone derivatives

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ABSTRACT

Benzoylation of D-galactono (**1a**), D-glucono (**2a**), and D-mannono-1,4-lactones (**3a**), or alkaline treatment of their corresponding perbenzoylated derivatives (**1b**, **2b**, and **3b**) afforded the same product. 2,6-dibenzoyloxy-hexa-2,4-dien-4-olide (**4**). Depending on the conditions employed, compound **4** was obtained as the single **4**-*Z* isomer, or as a **4**-*E* and **4**-*Z* diastereomeric mixture. Butenolide **4** arises from a double β-elimination process, which seems to involve an E1cB mechanism, as formation of **4** is not influenced by the relative orientation of the substituents in the starting aldonolactone. Hydrogenation of **4** gave stereoselectively the diastereoisomer having the D,L-*threo* configuration. Treatment of the lactonic disaccharide 2,3,5-tri-*O*-benzoyl-(2,3,5,6-tetra-*O*-benzoyl-β-D-galactofuranosyl)-D-galactono-1,4-lactone (**7**) with 20% triethylamine in dichloromethane afforded the diunsaturated derivative **8** as an *E*,*Z* mixture. Hydrogenation of **8** gave a 1:1 diastereomeric mixture of the 2(*S*),4(*R*) and 2(*R*),4(*S*)-3,5-dideoxylactones [**9**(*S*,*R*) and **9**(*R*,*S*), respectively], which indicates that no asymmetric induction attributable to the galactofuranose residue, took place during the hydrogenation reaction. As compounds **9**(*S*,*R*) and **9**(*R*,*S*) could be separated by h.p.l.c., a glycosylation reaction was employed for the resolution of the racemic dideoxylactone derivative **6**.

INTRODUCTION

Aldonolactone derivatives readily undergo β-elimination reactions under alkaline conditions to yield unsaturated lactones. We have previously described the occurrence of elimination reactions in aldono-1,4-lactones to afford 2(5*H*)-furanone (or 2-butenolide) derivatives[1–4]. Thus, benzoylation of D-galactono-1,4-lactone for long periods (16 h) gave 2,6-dibenzoylhexa-2,4-dien-4-olide (**4**), as a single isomer, but whose configuration for the exocyclic double bond was not determined[1]. In the present work, we describe the synthesis of butenolide **4**, starting from various benzoylated aldono-1,4-lactones, in order to assess the influence of the stereochemistry of the sugar on the elimination reaction. Also, the configuration for the C-4–C-5 double bond of **4** is now established.

Hydrogenation of **4** yielded[1] a racemic 3,5-dideoxylactone derivative (**5**), which proved now to be a single diastereoisomer, whose relative configuration for C-2 and C-4 is also established. Furthermore, in order to study the influence of chiral centers located

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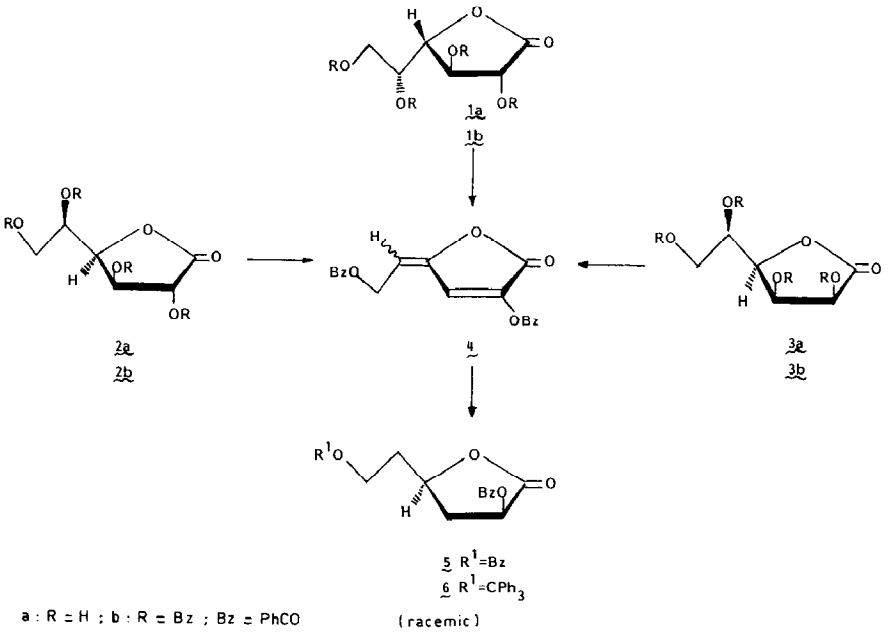
in the molecule, vicinal to the furanone system, on the stereochemical course of the hydrogenation, we applied the sequence of β-elimination–hydrogenation to the lactonic disaccharide 2,3,5-tri-*O*-benzoyl-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-D-galactofuranosyl)-D-galactono-1,4-lactone (**7**). Interestingly, the glycosylfuranone **8**, resulting from the double elimination of benzoic acid from **7**, may be considered as an analog derivative of ranunculine[5], a natural glycosyl-α,β-unsaturated-1,4-lactone precursor of the vesicant substance protoanemonin. On the basis of the results obtained for the hydrogenation of the glycosylbutenolide **8**, an approach for the resolution of a conveniently derivatized, racemic 3,5-dideoxyaldohexono-1,4-lactone, was developed.

RESULTS AND DISCUSSION

Benzoylation of D-galactono- (**1a**), D-glucono- (**2a**), or D-mannono-1,4-lactones (**3a**) with an excess of benzoyl chloride and pyridine for 16 h at room temperature afforded the same product: 2,6-dibenzoyloxy-2,4-hexadien-4-olide (**4**), as the result of the elimination of two molecules of benzoic acid. A single isomer of **4** crystallized from the mixture upon addition of ether in 44, 43, and 11% yield, respectively. The configuration of the exocyclic double bond was identified as *Z* (see later). The yield of butenolide **4** was improved by treating the perbenzoylated derivatives of the aldonolactones (**1b**, **2b**, and **3b**) with 20% triethylamine in dichloromethane, for 2 h at room temperature. For the three lactone derivatives the yields of **4** were >70%. However, under these conditions, a mixture of **4**-*E* and **4**-*Z* was obtained, as determined by the spectral data of the product. Thus, its ^{1}H-n.m.r. spectrum showed two double doublets for H-5, and two doublets for H-6 and H-6′. Also, in the ^{13}C-n.m.r. spectrum, all of the signals of the furanone system appeared duplicated, because of the mixture of isomers. The configuration of the double bond was assigned by comparison of the relative chemical shifts of H-5, H-6,6′ and C-3, C-4 for each isomer with those of similar compounds of known configuration[6,7]. An additional confirmation for the structure was obtained from the long-range allylic coupling constant values ($^4J_{3,5}$) of **4**-*E* ($\sim$1 Hz) and **4**-*Z* (not observed), as a transoid disposition for H-3 and H-4 gives a larger $^4J_{3,5}$ value[8].

The fact that the butenolide **4** is obtained in similar yields from perbenzoylated aldonolactones having *cis* or *trans* relationships for H-2 and the benzoyloxy group of C-3 indicates that the formation of **4** is not influenced by the relative orientation of substituents and supports the E1cB mechanism proposed for the elimination[3]. Thus, removal of H-2 by a base should lead to a resonance-stabilized carbanion, which rearranges with *syn* or *anti* elimination of the benzoyloxy group at C-3. This first elimination favors the removal of H-4, being the resulting carbanion stabilized by conjugation with an α,β-unsaturated carbonyl group, and also a E1cB mechanism would operate for the second elimination.

Catalytic hydrogenation of the mixture **4**-*E*,*Z* gave a racemic 3,5-dideoxyaldono-1,4-lactone (**5**, 78% yield) as a single diastereoisomer, according to its ^{13}C-n.m.r. spectrum. The ring-proton coupling constants from the ^{1}H-n.m.r. spectrum of **5** indicated a *threo* relationship for its chiral centers[2]. As observed for other diunsaturated



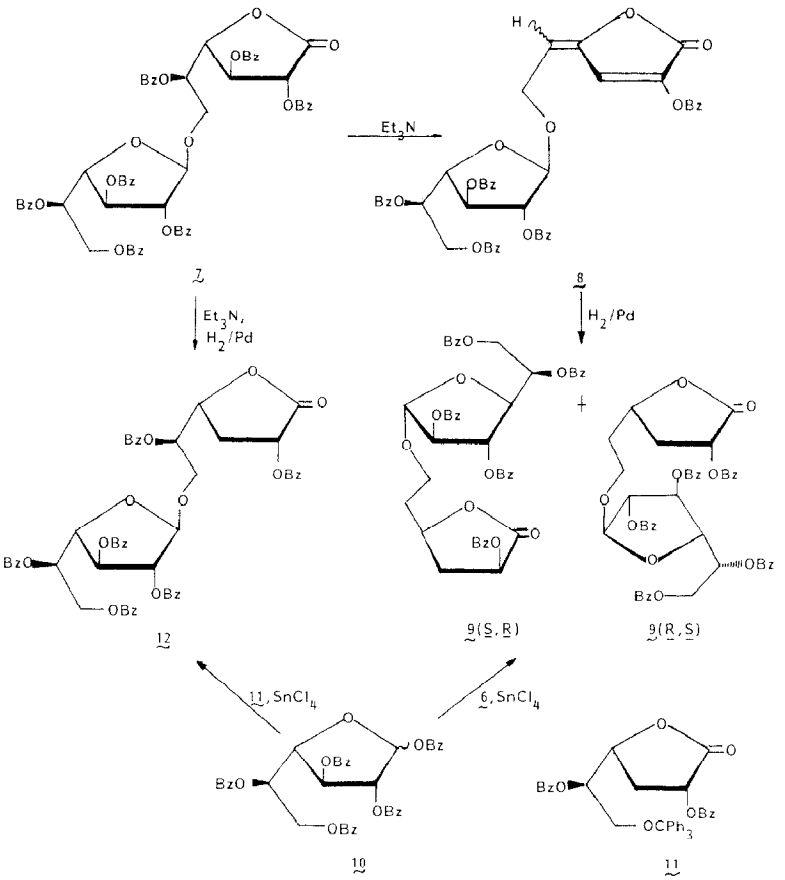
aldono-1,4-lactone derivatives[2,3], hydrogenation of **4** took place with high stereoselectivity, which is a consequence of the sequential saturation of the diunsaturated system. The exocyclic double bond is hydrogenated first[1], to give a racemic furan-2-one, whose lateral chain may now exert diastereofacial control for the hydrogenation of the endocyclic double bond, affording selectively the *cis* isomer.

The sequence of β-elimination–catalytic hydrogenation was also applied to the readily available[7] 2,3,5-tri-*O*-benzoyl-(2,3,5,6-tetra-*O*-benzoyl-β-D-galactofuranosyl)-D-galactono-1,4-lactone (**7**) in order to study the influence of the chiral centers vicinal to the ylidene–butenolide on hydrogenation. Treatment of **7** with 20% triethylamine in dichloromethane afforded the diunsaturated derivative **8**, which was actually a mixture of *E* and *Z* isomers, as evidenced by its ^{1}H-n.m.r. spectrum. Thus, the H-5 vinylic proton showed two signals at 5.84 and 5.62 p.p.m., which were assigned to the *E* and *Z* isomer, respectively, by comparison with the related butenolide **4**-*E*,*Z*. The ^{13}C-n.m.r. spectrum of the product confirmed the presence of both stereoisomers. However, a single isomer was obtained (30% yield) by reaction of **7** with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in acetonitrile. The signals for the furanone moiety in the ^{13}C-n.m.r. spectrum of the product greatly resembles that of **4**-*Z*; therefore a *Z* configuration was assigned for the exocyclic double bond. The signals for C-1′ (105.7 p.p.m.), C-2′ (81.4 p.p.m.), and C-4′ (82.5 p.p.m.) are characteristic of the β-D-galactofuranose unit[9,10].

Hydrogenation of **8** gave a chromatographically homogeneous product (87% yield), whose ^{13}C-n.m.r. spectrum revealed two clearly differentiated signals in the anomeric region (δ 106.1 and 105.4) in a 1:1 ratio, suggesting that a diastereomeric mixture had been obtained. Separation of this mixture could be achieved by h.p.l.c. (retention times 21.6 and 22.5 min). The compounds also differ in their optical rotation

values. In the ^{1}H- and ^{13}C-n.m.r. spectra of these products we could readily identify the signals due to the dideoxylactone and galactofuranose moieties. The relative configuration for the chiral centers originated by hydrogenation of **8**, was established as *threo*, since the chemical shifts and coupling constants for the lactone ring-protons were almost identical to those in the spectra of **5** and **6**. Therefore, the absolute configuration is 2(*S*),4(*R*) for one compound [named **9**(*S*,*R*)] and 2(*R*),4(*S*) for the other [**9**(*R*,*S*)]; however, with the data available we were not able to determine the identity of each individual compound. Furthermore, no evident asymmetric induction attributable to the chiral galactofuranose portion of the molecule took place during the hydrogenation, as **9**(*S*,*R*) and **9**(*R*,*S*) were obtained in similar proportions.

The fact that the stereoisomers **9**(*S*,*R*) and **9**(*R*,*S*) could be separated prompted us to attempt the resolution of racemic **5** employing a glycosylation reaction. For this purpose, a conveniently 6-*O*-substituted derivative[4] (**6**) of the dideoxylactone was used. Racemic **6** was condensed with penta-*O*-benzoyl-α,β-D-galactofuranose (**10**), in the presence of tin(IV) chloride as catalyst. As observed for similar condensations[9,11], the formation of the β-glycosylic linkage took place stereoselectively. The ^{1}H- and ^{13}C-n.m.r. spectra of the resulting product was identical to those of the mixture of **9**(*S*,*R*)



and **9** (*R,S*) obtained by hydrogenation of **8**. The diastereoisomers, separated by h.p.l.c., had the same physical and spectral properties as the products obtained by hydrogenation of **8**.

In order to obtain a glycosyl-3-deoxylactone derivative, the lactonic disaccharide **7** was hydrogenated in the presence of triethylamine and palladium. Under these conditions[12] the elimination of the C-3 benzoyloxy group was followed by immediate hydrogenation of the double bond, avoiding the second elimination of benzoic acid, and affording the 3-deoxylactone derivative **12**. The ^{1}H-n.m.r. spectrum of **12** showed two multiplets at 2.91 and 2.22 p.p.m., due to H-3a and H-3b, having *J* values similar to those observed for the same signals in compounds **5** and **6**, indicating the *threo* relationship for C-2 and C-4. The glycosyl-3-deoxylactone derivative (**12**) was also synthesized by the tin(IV) chloride-catalyzed condensation of 2,5-di-*O*-benzoyl-3-deoxy-6-*O*-trityl-D-*xylo*-hexono-1,4-lactone[4] (**11**) and penta-*O*-benzoyl-D-galactofuranose (**10**). The product (**12**) had the same physical and spectral properties as that obtained by hydrogenolysis of **7**. These results demonstrate that the chiral centers of the galactofuranose portion of the glycosyl-lactone **7** do not affect the stereoselection in the hydrogenation reactions. Furthermore, compounds **9** and **12** are suitable precursors, by reduction of the lactone function[9,11], for disaccharides having a deoxy sugar at the reducing end.

EXPERIMENTAL

General methods. — Melting points were determined with a Thomas–Hoover apparatus and are uncorrected. Optical rotations were recorded with a Perkin–Elmer 141 polarimeter. The ^{1}H-n.m.r. spectra were determined in $CDCl_3$, with a Varian XL-100 or a Bruker spectrometer, at 100 or 200 MHz, respectively. The ^{13}C-n.m.r. spectra (Table I) were recorded with a Varian XL-100 spectrometer at 25.2 MHz. H.p.l.c. was performed with a Micromeritics liquid chromatograph equipped with a refractive-index detector and a Micromeritics 771 injector, using a column (250 × 10 mm) Ultrasphere-ODS-2, RP-18 (5 μm) and 85:15 MeCN–H_2O at 2.45 mL × min^{-1}. T.l.c. was carried out on Silica Gel 60 F 254 (Merck) with 9:1 PhMe–EtOAc, and detection was effected by exposure to u.v. light or charring with 10% H_2SO_4 (v/v) in EtOH. Column chromatography was performed on Silica Gel 60 (Merck).

2,6-Dibenzoyloxy-2,4-hexadien-4-olide (**4**). — (A) *From* D-*galactono* (**1a**), D-*glucono* (**2a**), *and* D-*mannono-1,4-lactone* (**3a**). To a solution of **1a**, **2a**, or **3a** (1.0 g, 5.62 mmol) in dry pyridine (20 mL), BzCl (10 mL) was added. The mixture was shaken for 16 h at room temperature, and then poured into ice–water. After 3 h, the mixture was extracted with CH_2Cl_2 (30 mL, twice), and the extract was washed with 2% aq. HCl, water, and sat. aq. $NaHCO_3$, dried ($MgSO_4$) and the solvent evaporated. Benzoic acid and benzoic anhydride were removed by sublimation (70°, 0.1 torr), and the resulting syrup crystallized upon addition of ether. Recrystallization from EtOH afforded compound **4**-*Z* in 44, 43, and 11% yield from **1a**, **2a**, and **3a**; m.p. 127–128°, ^{1}H-n.m.r.: δ 8.40–7.30 (10 H, aromatic), 5.61 (H-5), and 5.18 (H-6,6').

TABLE I

^{13}C-N.m.r. data for compounds **4**–**6**, **8**, **9**, **11**, and **12**

Compound	*Chemical shift (δ, p.p.a.)*											
	C-1	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*C-1′*	*C-2′*	*C-3′*	*C-4′*	*C-5′*	*C-6′*
4*Z*	162.2	139.1	122.9	147.7	109.2	58.5						
4*E*	162.1	139.7	119.5	149.6	108.7	58.9						
5	171.7	69.0	35.2	74.1	34.9	60.7						
6	171.9	68.9	35.7*	74.5	34.9*	59.0						
8*Z*	162.2	138.8	123.0	146.7	111.2	61.4	105.7	81.4	77.5	82.5	70.2	63.1
8*E*	162.2	[a]	120.3	[a]	110.3	61.6	105.0	81.8	77.5	82.1	70.2	63.3
9[b]	171.7	69.0	35.6*	74.1	35.2*	63.3*	106.1	81.4*	77.5	82.0*	70.2	63.5*
9[c]	171.7	69.0	35.3	74.1	35.3	62.8*	105.4	81.5*	77.5	82.0*	70.3	63.3*
11	171.5	68.3	30.8	75.2	73.4	62.1						
12	171.0	68.0	30.2	74.4	71.5	64.6*	105.5	81.6*	77.3	82.0*	70.1	63.2*

* Indicates signals may be interchanged. [a] Not observed. [b,c] Corresponds respectively to the faster (retention time 21.6 min) and slower (22.5 min) migrating products by h.p.l.c. (see Experimental).

Anal. Calc. for $C_{20}H_{14}O_6$: C, 68.57; H, 4.00. Found: C, 68.47; H, 4.27.

(B) *From 2,3,5,6-tetra-*O*-benzoyl-*D*-galactono-*[1] *(***1b***),* D*-glucono-*[13] *(***2b***) and* D*-mannono-1,4-lactone*[14] *(***3b***).* Compound **1b**, **2b**, or **3b** (0.60 g, 1.0 mmol) was dissolved in 20% Et_3N–CH_2Cl_2 (10 mL) and stirred at room temperature, in the dark. After 2 h, no starting material was detected by t.l.c., and the mixture was diluted with CH_2Cl_2 (25 mL) and washed with HCl (5%), water and sat. aq. $NaHCO_3$. The organic extract was dried ($MgSO_4$) and the solvent evaporated to a syrup, which was filtered through a short column of silica gel using 4:1 hexane–EtOAc. Evaporation of the solvent afforded compound **4**-*E,Z*, which crystallized from ethanol in 72–78% yield; it had m.p. 122–127°; ^{1}H-n.m.r.: δ 8.40–7.30 (10 H, aromatic), 6.00 ($J_{3,5} \sim 1.0$, $J_{5,6}$ 7.5 Hz, H-5, **4**-*E*), 5.61 ($J_{5,6}$ 7.5 Hz, H-5, **4**-*Z*), 5.18 (H-6,6′, **4**-*Z*), and 5.07 (H-6,6′, **4**-*E*).

*2,6-Di-*O*-benzoyl-3,5-dideoxy-*D,L*-threo-hexono-1,4-lactone* (**5**). — Compound **4** (1.30 g, 2.86 mmol) dissolved in EtOAc (100 mL) was hydrogenated over 10% Pd on charcoal (200 mg), until the consumption of hydrogen ceased (8 h). The catalyst was filtered off and the solvent evaporated affording **5**, which crystallized from EtOH (0.90 g, 70%); m.p. 81–82°; ^{1}H-n.m.r.: δ 8.20–7.30 (10 H, aromatic), 5.75 ($J_{2,3}$ 9.2 Hz, $J_{2,3'}$ 10.3 Hz, H-2), 4.72 ($J_{3,4}$ 6.5 Hz, $J_{3',4}$ 10.1 Hz, H-4), 4.52 (2 H, H-6,6′), 3.01 ($J_{3,3'}$ 13.0 Hz, H-3), 2.27 (2 H, H-5,5′), and 2.15 (H-3′).

Anal. Calc. for $C_{20}H_{18}O_6$: C, 67.79; H, 5.09. Found: C, 67.92; H, 5.13.

(E) *And (*Z*)-2-benzoyloxy-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-2,4-hexadien-4-olide* (**8**). — To a solution of 2,3,5-tri-*O*-benzoyl-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-D-galactofuranosyl)-D-galactono-1,4-lactone[9] (**7**, 0.50 g, 0.47 mmol) in CH_2Cl_2 (48 mL), Et_3N (12 mL) was added and the mixture was stirred at 0°, in the dark. After 2 h, no starting material was detected on t.l.c., and the solution was diluted with CH_2Cl_2 (100 mL), washed with 5% aq. HCl, water and sat. aq. $NaHCO_3$, dried ($MgSO_4$), and the solvent evaporated. The residue was purified by column chromatography (49:1 PhMe–EtOAc). Fractions containing the product of R_F 0.52 were combined and evaporated to afford syrupy compound **8** (0.27 g, 70%), which precipitated from EtOH as an amorphous solid; $[\alpha]_D$ −22° (*c* 1, $CHCl_3$); ^{1}H-n.m.r. (200 MHz) *inter alia*: δ 5.84 (H-5, **8**-*E*), and 5.62 (H-5, **8**-*Z*).

Anal. Calc. for $C_{47}H_{36}O_{14}$: C, 68.44; H, 4.40. Found: C, 68.18; H, 4.68.

*(*Z*)-2-Benzoyloxy-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-2,4-hexadien-4-olide* (**8**-*Z*). — To a solution of compound **7** (0.30 g, 0.28 mmol) in dry MeCN (10 mL), 1,8-diazabicyclo[5.4.0.]undec-7-ene (DBU, 0.10 mL, 0.7 mmol) was added. The mixture was stirred for 2 h at 0°, in the dark, then treated as described for the preparation of **8**-*E,Z*. Compound **8**-*Z* was isolated by column chromatography; yield 0.07 g (30%); $[\alpha]_D$ −18° (*c* 1, $CHCl_3$). ^{1}H-n.m.r. (200 MHz): δ 8.20–7.15 (25 H, aromatic), 6.05 (H-5′), 5.65 (H-3′), 5.62 (H-5), 5.48 ($J_{2',3'}$ 1.0 Hz, H-2′), 5.32 ($J_{1',2'} < 1.0$ Hz, H-1′), 4.90–4.30 (5 H, H-4, 6a, 6b, 6′a, 6′b).

*2(*S*),4(*R*) And 2(*R*),4(*S*)-2-*O*-benzoyl-3,5-dideoxy-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-hexono-1,4-lactone* [**9**(*S,R*) and **9**(*R,S*)]. — (A) *Starting from 2-benzoyloxy-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-2,4-hexadien-4-olide* (**8**). Compound **8** (0.21 g, 0.25 mmol) dissolved in EtOAc (15 mL) was hydro-

genated over 10% Pd–charcoal at 0° for 3 h, when no starting material was observed by t.l.c. The catalyst was filtered and the solution evaporated to a syrup, which was chromatographed with 19:1 PhMe–EtOAc. Fractions containing the product of R_F 0.36 were combined and the solvent evaporated to afford the diastereomeric mixture **9**(*S*,*R*) and **9**(*R*,*S*); $[\alpha]_D$ −9° (*c* 1, $CHCl_3$); ^{13}C-n.m.r. (anomeric region): δ 106.1 and 105.4 (1:1 ratio).

Anal. Calc. for $C_{47}H_{40}O_{14}$: C, 68.11; H, 4.86. Found: C, 68.36; H, 5.07.

The components of the mixture were separated by h.p.l.c. The compound having a retention time of 21.6 min crystallized from EtOH; m.p. 64–69°, $[\alpha]_D$ −1° (*c* 2, $CHCl_3$); ^{1}H-n.m.r.: δ 8.15–7.15 (25 H, aromatic), 6.07 (H-5′), 5.78–5.55 (H-2,3′), 5.45 ($J_{2',3'}$ 2.0 Hz, H-2′), 5.32 ($J_{1',2'}$ <1.0 Hz, H-1′), 4.86–4.58 (H-4,4′,6′a,6′b), 3.94, 3.74 (H-6a,6b), 2.94 ($J_{3a,3b}$ 13.0, $J_{2,3a}$ 9.2, $J_{3a,4}$ 6.3 Hz, H-3a), and 2.36–1.90 (H-3b,5a,5b). The other component (retention time 22.5 min) was also obtained crystalline from EtOH; m.p. 69–71°, $[\alpha]_D$ −26° (*c* 1, $CHCl_3$); ^{1}H-n.m.r.: δ 8.18–7.15 (25 H, aromatic), 6.07 (H-5′), 5.70–5.56 (H-2,3′), 5.41 ($J_{2',3'}$ ~1.0 Hz, H-2′), 5.30 ($J_{1',2'}$ <1.0 Hz, H-1′), 4.82–4.64 (H-4′, H-6′a,6′b), 4.10–3.58 (H-6a,6b), 2.92 ($J_{3,3'}$ 13.0 Hz, $J_{3,4}$ 6.4 Hz, $J_{2,3}$ 9.2 Hz, H-3a), and 2.28–1.96 (H-3b,5a,5b).

(B) *By condensation of 1,2,3,5,6-penta-*O*-benzoyl-α,β-*D*-galactofuranose*[9] (**10**) *with 2-*O*-benzoyl-3,5-dideoxy-6-*O*-trityl-*D,L-threo-*hexono-1,4-lactone*[4] (**6**). — To a solution of compound **11** (0.35 g, 0.50 mmol) in dry CH_2Cl_2 (5 mL) cooled at 0°, $SnCl_4$ (0.07 mL, 0.54 mmol) was added. The solution was stirred for 10 min followed by the addition of compound **6** (0.25 g, 1.50 mmol). After stirring for 15 h at room temperature the mixture was monitored by t.l.c., showing a main product which had the same mobility (R_F 0.36) as the mixture **9**(*S*,*R*) and **9**(*R*,*S*). The solution was poured into aq. $NaHCO_3$ and extracted with CH_2Cl_2. The organic extract was washed with water, dried ($MgSO_4$) and evaporated. Purification of the residue by column chromatography with 19:1 PhMe–EtOAc, afforded a syrup (0.28 g, 68%) having the same spectral properties as the product **9** from (A).

*2,5-Di-*O*-benzoyl-3-deoxy-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-*D*-xylo-hexono-1,4-lactone* (**12**). — (A) *By hydrogenolysis of 2,3,5-tri-*O*-benzoyl-6-*O*-(2,3,5,6-tetra-*O*-benzoyl-β-*D*-galactofuranosyl)-*D*-galactono-1,4-lactone* (**7**). Compound **7** (0.38 g, 0.36 mmol) dissolved in EtOAc (16 mL) and Et_3N (4 mL) was hydrogenated over 10% Pd–charcoal under pressure (3 atm.), for 6 h, when t.l.c. examination of the reaction mixture showed a main product (R_F 0.39), slower-migrating than the starting material (R_F 0.44). The mixture was diluted with CH_2Cl_2 and filtered. The filtrate was washed with 5% aq. HCl, water, aq. $NaHCO_3$ and water, dried ($MgSO_4$) and the solvent evaporated. Upon addition of EtOH compound **7** was obtained as a chromatographically homogeneous, amorphous solid (0.31 g, 86%); $[\alpha]_D$ −30° (*c* 1, $CHCl_3$); ^{1}H-n.m.r. (200 MHz): δ 8.15–7.20 (30 H, aromatic), 6.08 (H-5′), 5.70–5.35 (H-2,3′,5), 5.46 ($J_{2',3'}$ <1.0 Hz, H-2′), 5.40 ($J_{1',2'}$ <1.0 Hz, H-1′), 4.98 (H-4), 4.82–4.64 (H-4′, H-6′a,6′b), 4.14 ($J_{5,6a}$ 6.0, $J_{6a,6b}$ 10.0 Hz, H-6a), 3.96 ($J_{5,6b}$ 6.0 Hz, H-6b), 2.91 ($J_{2,3a}$ 9.6, $J_{3a,4}$ 6.5, $J_{3a,3b}$ 13.0 Hz, H-3a), and 2.22 ($J_{2,3b}$ 10.2, $J_{3b,4}$ 9.6 Hz, H-3b).

Anal. Calc. for $C_{54}H_{44}O_{16}$: C, 68.35; H, 4.67. Found: C, 68.59; H, 4.90.

(B) *By condensation of 1,2,3,5,6-penta-*O*-benzoyl-α,β-*D*-galactofuranose*[9] (**10**) *with 2,5-di-*O*-benzoyl-3-deoxy-6-*O*-trityl-*D*-xylo-hexono-1,4-lactone*[4] (**11**). To a solution of **10** (0.28 g, 0.40 mmol) in dry CH_2Cl_2, $SnCl_4$ (0.05 mL, 0.4 mmol) was added, and the solution was stirred for 10 min at 0°. Compound **11** (0.25 g, 0.40 mmol) was then added, and the mixture was stirred for 15 h at room temperature. The mixture was treated as described for the preparation of **9**, and purified by column chromatography (19:1, PhMe–EtOAc), to yield compound **12** (0.25 g, 66%), which had the same physical constants and spectral properties as the product from (A).

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